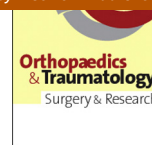




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Technical note

Use a simple lower limb outrigger frame in intramedullary nailing fixation of a floating knee



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ABSTRACT

Closed intramedullary nailing is a classical therapeutic approach for floating knee injuries. An appropriate positioning is critical for a successful surgery. However, there is a lack of an ideal auxiliary device to facilitate the implantation of intramedullary nail. The authors developed a simple lower limb outrigger frame (SLOF), which is made of nylon, to facilitate the nail implementation process. The SLOF could be radiolucent and autoclavable. A total of 31 patients with floating knee injury underwent the closed intramedullary nailing assisted by SLOF. The average operative duration was 91.0 min, and all tibial and femur fractures reached bony union. The SLOF could assist well insertion of intramedullary nail for the treatment of floating knee injuries, with the advantages of simple operation, less manpower, easy imaging access but less radiation exposure, and more cost-effectiveness.

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1. Introduction

Fraser et al. had classified floating knee injuries into type I for pure diaphyseal fracture and type II for fractures of both the tibia and femur with extension of either fracture into the knee [1]. The minimally invasive technique of either retrograde or anterograde nailing for femur and tibia by intra-patella tendon or pare-patella tendon approach had been reported for Fraser I type [2], indicating that complex fractures could be treated with a single small incision. In this procedure, approximately 40° knee flexion is needed for retrograde femoral nailing [3,4], while an anterograde tibia nailing needs a knee flexion of more than 90° [5,6]. A strong support is very important for fracture reduction and successful nailing while the knee is in “floating” state. In the existing literature, a sterile towel or other supports are used to maintain knee flexion, at the same time one or more assistants are needed to help stabilize the injured limb in a flexed position [2]. But these supports can’t conveniently assist us in nailing operation for floating knee injuries.

Therefore, we developed a simple lower limb outrigger frame (SLOF) as a support for floating knee injury. Our hypothesis is that the SLOF could provide a stable support for floating knee

injury and make it easy to perform fracture reduction and nailing operation.

2. Technique

2.1. Characteristics and usage of SLOF

SLOF is made from three radiolucent and heatproof nylon plates with a thickness of 15 mm, width of 150 mm, and length of 150 mm in the adjustable plate, 350 mm in base plate. The adjustable plate and base plate are connected by a saw-toothed stainless steel hinge. The locking wrench helps tightening or loosening of the two plates. The two plates can move freely between a folded or unfolded position from a range of 0 to 180 degrees. The length of the adjustable plate is fixed by small locking bolts on both sides to adapt to the different lengths of injured limbs (Fig. 1). The SLOF can be repeatedly used after folding, packaging and autoclaving.

2.2. Surgical procedure

The patient is placed in the supine position on the radiolucent operating room table. No tourniquet is applied, a transpatellar tendon approach is performed to reveal proximal tibia. The injured limb is placed over the sterile SLOF after it is unfolded to a triangle frame. It is easy to flex the knee joint to more than 90 degrees by

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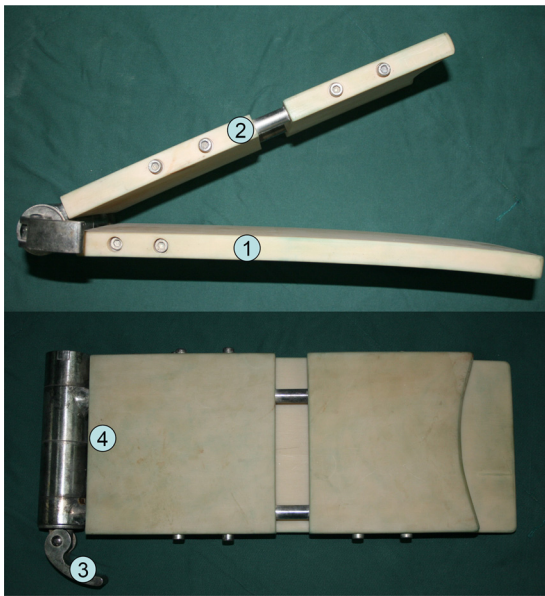


Fig. 1. The SLLOF: Base plate; adjustable plate; locking wrench; toothed stainless steel hinge.

adjusting the SLLOF. To prevent the injury of local blood vessels and nerves, the folded sterile sheet is placed to popliteal fossa (**Fig. 2A**). The length is adjusted in accordance with the limb length and the triangle frame is fixed by the locking wrench. If the limb is long enough, the adjustable plate is prolonged or move the base plate upward. Due to the superficial location of tibia, reduction of fracture and modulate rotation of leg by operator's hands can be easily performed after observing whether internal or external rotation deformity exists. Fracture reduction is achieved and maintained

by longitudinal manual traction. Then reaming and nailing is performed using tibial titanium Interlocking Nails (Shandong Weigao Group Medical Polymer Co., Limited). The injured limb is then steadily supported by a SLLOF and the contralateral limbs flattened naturally in the radiolucent operating table for imaging. The antero-posterior (AP) and lateral images are obtained by just turning the C-arm to be perpendicular to the injured limb without changing the position of both limbs. If necessary, the angle of the SLLOF can be reduced for AP images (**Fig. 2B**). The angle of SLLOF is adjusted to keeping the knee joint fixed 40° to 60° position for femoral nailing. After identification of the entry point of femoral intercondylar notch from the same incision, precise reduction, control of rotation, maintenance of the limb alignment are obtained by tibial manual traction. If needed, AO-Femoral Distractor or Skeletal Joysticks may be used for the optimal reduction, limited open reduction as a last resort, especially in obese and very muscular patients. Then reaming and nailing is performed. Both the proximal locking of the femur and the distal locking of the tibia are performed with the help of the matched sighting device.

3. Preliminary results

Thirty-one cases with Fraster type I floating knee injury were treated with intramedullary nails with the assistance of SLLOF from October 2006 to October 2011 (**Table 1**). The average operative duration was 91.0 min (60–140 min). The average fluoroscopic time was 66s (40–125 s). In 8 patients, use of AO distractor was necessary for optimal reduction. In 3 patients limited open reduction was necessary because of obesity and strong muscles. One case developed symptomatic pulmonary fatty embolism after surgery, and the symptoms were relieved after treatment. There were no deep infection, skin necrosis, nerve palsies, iatrogenic neurovascular injury, compartment syndrome, or death,

With a mean follow-up of 18 months (12–24 months), all tibial and femur fractures reached bony union (**Fig. 3**). The mean

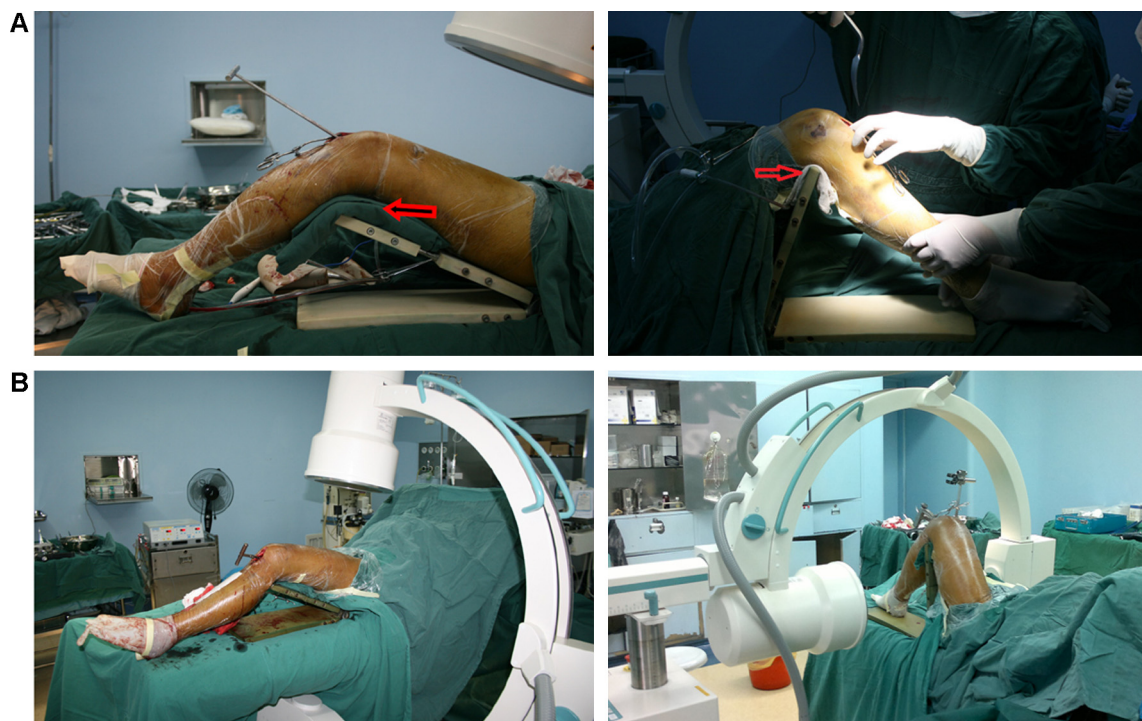


Fig. 2. Schematic diagrams of intraoperative tibial and femoral nailing using SLLOF and fluoroscopy. A. The soft pad is placed to the popliteal fossa while using SLLOF. B. The degree is adjusted and the triangle frame is fixed by the locking wrench while using fluoroscopy.

Table 1Preoperative data of patients ($n = 31$).

Age in years, mean (range)	35.8 (23–56)
Sex	
Male (n)	25
Female (n)	6
AO/OTA classification of femur	
A (n)	12
B (n)	13
C (n)	6
AO/OTA classification of tibia	
A (n)	10
B (n)	16
C (n)	5
Closed fracture (n)	24
Open fracture (n)	7 (All at tibial level)
Gustilo I (n)	4
Gustilo II (n)	3

time of bony union of the tibia was 12.4 (10–23) weeks, and of the femur 14.3 (11–24) weeks. Three cases demonstrated delayed union (more than 16 weeks), and obtained ultimately bony union by dynamization of the nail in 8 weeks. A mal-union was found in one case with external deformity of 16° (The criteria of fracture mal-union included angular and/or rotation greater than 15°) [7].

4. Discussion

Intramedullary nailing is the treatment of choice for floating knee type I with excellent outcome in over 80% patients [2,4,8–10], but the postoperative complication rate is about 24.8% [11]. Positioning of the patient is crucial to the success of closed intramedullary nailing with less complications. In this study, one case developed pulmonary fatty embolism, three cases demonstrated delayed union, one case demonstrated external mal-union. Thus, the overall complications rate of the SLLOF technique in this study is 16.1%.

The knee is usually flexed with the assistance of sterile towels, a folded pillow [2,12], a triangle support, a horizontal bar with traction [13] or by the adjustment of orthopedic operating table during operation [4,5,14,15]. It is difficult to achieve a strong support with the soft supports such as sterile towels, folded pillow, etc, so that the surgery operation is performed while the injured knee is still in “floating” or “swing” state. The triangular support cannot adjust the angle and length, so that it is difficult to adapt to the variable angle

of nailing operation of the floating knee injury and individual differences in limb length. Adjusting the angle of the operating table has served as the gold standard for indirectly reduction during internal fixation procedures for many years. However, it is obviously complex and time-consuming in case of multiple trauma [6], which increases the risk of contamination and is not optimal for obese patients with limited morbidity [14]. The SLLOF is placed beneath popliteal fossa of the injured extremity. After adjusting appropriate angle and length, such device exhibits a much stronger supportive effects than others, thereby reducing the physical exertion of the surgeons. The SLLOF technique needs a minimum number of assistants.

The femoral fracture is usually stabilized first [2,10]. Of the most important reason is that unstable femoral fracture might displace and cause more soft-tissue injury when the knee is flexed for nailing of the tibia. Thus, it is more convenient to perform tibia nailing with the knee and hip flexed after fixation of femur. But, in our study, with the SLLOF, the leg is securely supported even in a hyper-flexed position, which gives some flexibility for the order of nailing. Surgeons can operate depending on their habits, preferences and the types of fracture. Naturally, the treatment of a simple fracture firstly is beneficial to another complex fracture. Therefore, in this study, tibial fracture is stabilized first.

The board length and angle of SLLOF are adjustable, which allows to obtain a certain tension force on the injured limb, thus, facilitating fracture reduction. Wood et al. [13] report that the knee with a hyper-flexed position could help prevent mal-union for proximal tibia fractures. Such device is particularly important for tibia nailing in that hyper-flexed position which helps locate the entrance point, thereby lowering the risk of the damage to the patella and patellar tendon. Reduction of fracture can be easily maintained through body gravity and manual traction with the assistance of either the SLLOF technique, or Seyhan’ method [15]. The latter could result in exaggerated oedema at the fracture site in 28.6% cases. However, with the SLLOF technique no oedema at the fracture site has been observed in all the cases of this study.

The fluoroscopy time with the SLLOF technique is significantly shorter than in the literature [16]. In addition, the practicing surgeons are well away from the radiation beam because of the support of SLLOF.

The SLLOF as a support for femoral and tibial nailing has showed some advantages. Fraser type I floating knee injury, moreover, single fracture of the femoral diaphysis or tibial diaphysis are the indications of SLLOF technique.

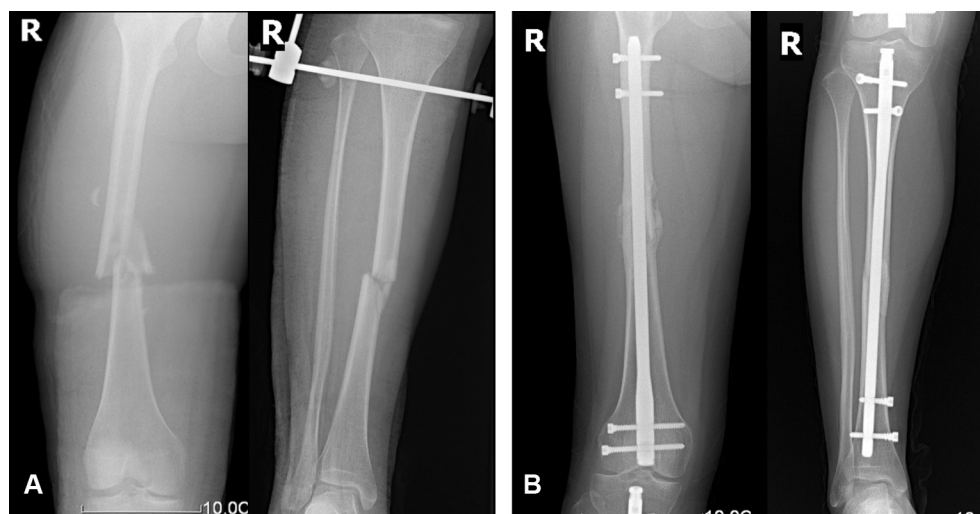


Fig. 3. Radiographic overview of one case with floating knee injury. A. Preoperative radiograph of ipsilateral femur and tibia. B. Four months postoperatively, the radiograph demonstrates that the fractures of femur and tibia approaches to bony union.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Acknowledgments

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